Complementarity, Coordination, and Credit[*]

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Abstract

We consider a start-up firm which applies for a bank loan to implement a project based on complementary activities. The firm has the possibility to improve the complementarity effect by coordinating the activities. Coordination is costly and can be made either by using internal human resources or by hiring a consulting firm. In the former case the choice of coordination is not verifiable by the bank and a moral hazard problem arises, while in the latter information is symmetric. The role of consulting services is thus to mitigate the informational problem. Without consulting, the firm does not coordinate and either obtains no funding or the surplus of the project is not maximized.

Keywords: complementarity, inside and outside coordination, moral hazard.

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"Progress in the specific is thwarted by failures in the general".[1]

1 Introduction

The study of the organizational and technological structure of the firm has been recently enriched by the analysis of complementarity that can arise between different activities which constitute a production project. The marginal return from implementing a certain activity can be increased in the presence of other types of activities. However, scant attention has been devoted to the means through which the firm obtains the initial resources that are often necessary to finance investment projects. The present paper provides a link between two different streams of literature: firm's innovative activity and financial contracting. Our aim is to build a framework to analyse situations in which the exploitation of complementarity depends on the access to external finance.

We consider a risk-neutral start-up entrepreneurial firm which could potentially act as a monopolist by exploiting a patent on a new product. Nonetheless, the initial structure of demand and cost functions are such that equilibrium production is zero. The firm then decides to invest in a project based on two different activities aiming at demand enhancing and cost reducing, respectively, but is wealth constrained. The former stochastically enlarges market demand while the latter stochastically decreases unit cost of production. For the sake of simplicity, we will refer to marketing as the demand enhancing activity and to (process) R&D as the cost reducing activity.[2]

An important feature of the model is that the nature of the two activities makes the joint investment more profitable than the sum of the separate investments, i.e., the two activities are complementary. The study of interconnected subsytems linked by complementarity relationships has been applied to the theory of firm (Milgrom and Roberts, 1990 and 1995) and has revealed the existence of different types of investments that increase their respective marginal returns when they are undertaken at the same time. In particular, Athey and Schmutzler (1995) and Lin and Saggi (2002) investigate the relationship between process and product innovation and show that firms invest more in product innovation when they can undertake also process innovation.

In our model we assume that the two activities are performed by independent units inside the firm. The introductory quotation from Kling *et al.* (1992) refers to the general fact that specialization is a fundamental aspect of economic systems because it permits greater accomplishments. Nonetheless, it could reduce the individual's ability to deal with the full array of resources available

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[1] Kling *et al.* (1992).

[2] This definition of marketing is very general and encompasses different types of activities that are often linked to demand enlargement, e.g., product innovation and advertising.

in the economic environment. We explicitly consider the possibility of the firm to overcoming the dilemma by coordinating the interdependency among specialized individuals, groups, or subunits.[3] Surplus of the project is maximum when activities are coordinated.

The management literature recognizes the positive effects of intraorganizational coordination - the creation of a system that catalyses the flows of information originated in each unit and allows for a more efficient usage of resources.[4] In particular, many works tend to analyse coordination through computerization in manufacturing systems and specify the relative effects on agency and transaction costs, with the aim of studying the internal organization and the optimal size of the firm (Kling *et al.*,1992; Gurbaxani and Whang, 1991; Kling *et al.*,1996).

We start from a different perspective. In our model coordination can be made either by using internal resources (i.e., *inside mode*) or by hiring a consulting firm that provides the connection between the units of the firm (i.e., *outside mode*). We justify this assumption on the basis of the stylized fact that very often consulting firms are hired to reinforce and confirm the necessity of adopting some drastic measures rather than to provide new solutions to existing problems. As we will show, agency costs arise when the firm chooses the internal mode and take the form of informational rent paid by the bank that lends money to the firm. When the firm turns to the market to obtain coordination services, it gives up the rent and no agency costs are present. We do not study how coordination is technically implemented and we consider no separation between ownership and control of the firm; in addition, we abstract from the transaction costs related to using the market to procure what the firm needs instead of making it itself.

The firm is endowed with a certain amount of initial capital which is not enough to finance the project: as anticipated above, it needs external finance. It is well known in the corporate finance literature that bank finance is the main source of funding for start-up firms. Jensen and Meckling (1976) and Myers and Majluf (1984) show, in their seminal papers, that (bank) debt is

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[3]Consider for example a preliminary market research that indicates that consumers prefer certain features of the good. The marketing unit can tailor the advertising campaign to highlight such features, while the R&D unit can reduce costs by saving on the less attractive features. Consumers' satisfaction increases, thus raising the probability of success of both activities.

[4]The rise of computerized networks has made it possible to codify, store and share different kinds of infomation more easily and cheaply than before. Recent knowledge management practises based on CIT (Communication and Information Technology) have driven firms to adopt softwares like the ERP (Enterprise Resource Planning) to integrate all departments and functions of a company into a single computer system that can serve all different departments' particular needs. Each department usually has its own computer system optimized for the particular task that the department does. ERP combines them all together into a single and integrated software program that runs off a single database. In this way the various departments can more easily share information and communicate with each other.

the most efficient way of financing when there is no separation between ownership and control and, respectively, incentive or information problems. In a more recent contribution, Petersen and Rajan (1994) argue that a start-up firm benefits from building close ties with a bank because it increases the availability of financing. On the basis of these features we assume that the firm will apply for a bank loan to implement both activities. We consider a risk-neutral monopolistic bank that designs the loan. The bank's outside option is represented by investing in alternative activities. When the firm chooses the inside mode a moral hazard problem arises (Holmstrom, 1979; Stiglitz and Weiss, 1981) because the coordination cost is non transferable. The firm decides whether to bear the cost or not after the contract is signed and we assume that the bank cannot verify the choice. On the contrary, when the firm decides to avail itself of an outside consulting service, the coordination cost becomes transferable and the amount of borrowing reveals the information. The firm demands in fact an amount equal to the sum of investment plus coordination costs. The bank knows then that the firm will implement coordination because otherwise it will incur very high rescission costs to cancel the contract with the consulting agency.

At equilibrium we consider the interest rate proposed by the bank as a function of the coordination cost and its implication for the level of surplus, defined as the sum of the bank's utility and the firm's utility. We focus in particular on two different scenarios, depending on the utility level that the bank extracts from the complementary project relative to its outside options. For relatively low levels of complementarity, the firm chooses the outside mode because by hiring a consulting agency it gains access to funds. Moreover, we show that surplus is at its highest. On the contrary, for relatively high levels of complementarity, the firm is indifferent between the two modes because there is no threat of credit rationing. We verify that surplus is not maximized when the inside mode is chosen because the firm prefers not to coordinate, whereas surplus is efficient under the outside mode because such a choice represents a credible promise of coordination.

In our framework the role of consulting services is to mitigate the informational problems. If the firm decides not to resort to them, either it obtains no funding or it does not maximize surplus. On the contrary, if the firm avails itself of the consulting surplus is at its highest, because the firm always coordinates.

The remainder of the paper proceeds as follows. Section 2 introduces the basic model and its main assumptions. Section 3 and 4 study the characteristics of the loan under inside and outside mode of coordinating, respectively. Section 5 considers the equilibrium analysis. Finally, Section 6 provides the main conclusions.

2 The Model

In this section we describe the complementary nature of the project and the possibility of improving the complementarity effect by coordinating the activities. We then define the inside and the outside modes of coordination and we introduce financial constraints for the firm. The last part summarizes the contracting game between the bank and the firm and the timing of the model.

2.1 Complementarity

Consider a risk-neutral monopolistic firm that, at $t = -1$, faces demand $P = a - Q/4$ and whose marginal production cost is constant and equal to c. The equilibrium quantity is $Q = 2(a - c)$ and the equilibrium profit is $(a - c)^2$. Let $a = c$: the firm does not produce because the demand is relatively low (or, equivalently, because the cost is relatively high). At $t = 0$ the firm can invest a fixed amount K_a in a marketing activity that shifts a by Δ_a with probability p and by 0 with probability $(1 - p)$, and a fixed amount K_c in a R&D activity that lowers c by Δ_c with probability q and by 0 with probability $(1 - q)$. At $t = 1$, once uncertainty is resolved, the firm starts producing.

We formalize the notion of complementarity between the two activities on which the project is based to show that the firm always prefer the joint investment in the two activities. Let $\Pi(i, j)$ define (net) expected surplus of the investment, where i (j) $= \{1, 0\}$ denote whether marketing (R&D) activity is implemented or not. We obtain that:

1. $\Pi(0, 0) = 0$ represents surplus when the firm does not invest at all (in such a case it would not produce as well).

2. $\Pi(1, 0) = p\Delta_a^2 - K_a$ represents expected surplus when the firm only finances the marketing activity; demand shifts with probability p, the firm sets an equilibrium quantity equal to $2(\Delta_a)$ and gets an equilibrium profit equal to Δ_a^2; with probability $(1 - p)$ demand is stuck and the firm does not produce.

3. $\Pi(0, 1) = q\Delta_c^2 - K_c$ represents expected surplus in case of investment in R&D; production costs decrease with probability q, the firm sets an equilibrium quantity equal to $2(\Delta_c)$ and gets Δ_c^2; with probability $(1 - q)$, as before, the firm does not produce.

4. $\Pi(1, 1) = pq(\Delta_a + \Delta_c)^2 + p(1 - q)\Delta_a^2 + q(1 - p)\Delta_c^2 - (K_a + K_c)$ represents expected surplus in case of simultaneous investment in marketing and R&D; with probability pq both activities succeed, hence equilibrium quantity and profit are given respectively by $2(\Delta_a + \Delta_c)$ and $(\Delta_a + \Delta_c)^2$; with probability $p(1 - q)$ only marketing succeeds, then the firm produces $2(\Delta_a)$ and obtains Δ_a^2; with probability $q(1 - p)$ only R&D succeeds, then the firm produces $2(\Delta_c)$

and obtains Δ_c^2; finally, with probability $(1-p)(1-q)$ both activities fail and the firm does not produce.

Assume for simplicity that $q = p$. We have that:

$$\Pi(1,1) = p^2 (\Delta_a + \Delta_c)^2 + p(1-p)\Delta_a^2 + (1-p)p\Delta_c^2 - (K_a + K_c) \tag{1}$$

It is easy to verify that:

Proposition 1 Π *is a supermodular function on* $\{0,1\} \times \{0,1\}$, *i.e.,*

$$\Pi(1,1) + \Pi(0,0) \geq \Pi(1,0) + \Pi(0,1).$$

Proof. By solving the above inequality one easily finds that:

$$[\Pi(1,1) + \Pi(0,0)] - [\Pi(1,0) + \Pi(0,1)] = p^2 2\Delta_a\Delta_c > 0,$$

where $p^2 2\Delta_a\Delta_c$ represents the expected value of the complementarity gain. ∎

Surplus due to the simultaneous implementation of both activities exceeds the sum of the individual surpluses. This formalizes the notion of complementary investment opportunities.

2.2 Coordination

In our model we introduce the possibility of streamlining the production process by improving the complementarity effect. This happens when the firm chooses to coordinate the units that are responsible for each activity at a (fixed) cost C. Assume, again for simplicity, that coordination makes the probability of success of each activity perfectly correlated. Let $\Pi^C(1,1)$ the expected surplus of the project with coordination, which derives from the following contingent production plan: either both activities succeed with probability p, then the firm sets $2(\Delta_a + \Delta_c)$ and obtains $(\Delta_a + \Delta_c)^2$, or both fail, with probability $(1-p)$, and the firm does not produce. Surplus is:

$$\Pi^C(1,1) = p(\Delta_a + \Delta_c)^2 - (K_a + K_c) - C. \tag{2}$$

Let coordination be efficient, i.e.,

$$\Pi^C(1,1) \geq \Pi(1,1),$$

which, after rearranging, gives the following condition:

$$C \leq (p - p^2) 2\Delta_a\Delta_c = \overline{C}. \tag{3}$$

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Condition (3) will hold throughout the paper. The coordination cost is thereby sufficiently low to ensure that coordination increases the expected value of the complementarity gain.

We allow two different options regarding the mode of coordinating: on the one hand, the firm can choose to employ internal resources to ameliorate the flow of information between the marketing and the R&D unit, i.e., it performs *inside* coordination. On the other hand, it can choose to delegate this task to a consulting company against the payment of a fixed amount. This will be referred to as *outside* coordination. For the sake of simplicity, we assume that both inside and outside coordination costs are equal to C.

2.3 Credit

We study the case in which the firm has an initial endowment equal to $K_c < K_a$ that can be invested either in R&D or in the bond market where B_f is the gross interest rate.[5] In the former case the firm gets $\Pi(0,1)$, while $(B_f - 1) K_c$ represents the return in the latter one. Let $(B_f - 1) K_c > \Pi(0,1) \iff \Delta_c^2 < \dfrac{B_f K_c}{p}$. Without financial aid the firm invests in bonds: $\overline{U} = (B_f - 1) K_c$ represents its outside option.

The firm can borrow from a risk-neutral monopolistic bank the amount of money necessary to finance the investment project. We suppose that there are many firms with good projects and fewer banks looking for good investment opportunities, so that our bank has all the bargaining power. The bank designs a loan $[R]$, where R is the gross interest rate and a limited liability constraint is specified for the firm.

If the firm chooses not to coordinate, surplus amounts to $\Pi(1,1)$ and the borrowing to K_a. Let $\Delta_c^2 < K_a$: when only R&D succeeds, the firm goes bankrupt even if $R = 1$. Surplus is thus shared between the firm and the bank in the following way:

$$U = p^2 \left[(\Delta_a + \Delta_c)^2 - RK_a \right] + p(1-p) \max \left\{ \Delta_a^2 - RK_a,\, 0 \right\} - K_c \tag{4}$$

is the utility of the firm and

$$V = p^2 RK_a + p(1-p) \min \left\{ RK_a,\, \Delta_a^2 \right\} + (1-p) p \Delta_c^2 - K_a \tag{5}$$

the utility of the bank.

On the other hand, when marketing and R&D are coordinated surplus is $\Pi^C(1,1)$. If the firm selects the internal mode of coordination, the amount C is assumed to be nonmonetary and

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[5] The assumption $K_c < K_a$ reflects the stylized fact that investing to expand market size is generally more costly than investing to lower the cost of production. Note that the strategy of investing αK_c, with $0 < \alpha < 1$, in one activity and $(1-\alpha) K_c$ in the other, which again exploits complementarity, is not available, because we assume that the costs required to implement the two activities are indivisible.

nontransferable and the bank has to directly monitor the units responsible for the two activities in order to observe whether the firm coordinates or not. We assume that the cost of monitoring is infinite, hence the bank cannot verify the choice of the firm: a form of moral hazard is present. Borrowing amounts to K_a and utility of the firm and of the bank are respectively given by:

$$U^C = p\left[(\Delta_a + \Delta_c)^2 - RK_a\right] - (K_c + C),$$ (6)

$$V^C = pRK_a - K_a.$$ (7)

If the external mode is implemented C is assumed to be monetary and transferable. The firm then applies for $(K_a + C)$ and reveals that it wants to coordinate: no moral hazard problem arises because the choice of coordination is made before the contract and we assume that it is verified by the bank. Surplus $\Pi^C(1,1)$ is shared between the firm and the bank as follows:

$$U'^C = p\left[(\Delta_a + \Delta_c)^2 - R(K_a + C)\right] - K_c,$$ (8)

$$V'^C = pR(K_a + C) - (K_a + C).$$ (9)

In other words, the bank has only to check the invoice of the consulting firm when coordination is outside. We assume that the cost of this operation is zero. The problem of credibility of the firm's commitment to coordinate will be solved by assuming that the bank observes and verifies a conveniently high cost F of cancelling the contract between the firm and the consulting company.

The bank's outside option is to invest in alternative assets which give an utility equal to $\overline{V}$.

2.4 Game and Timing

The contracting game between the two agents is defined as follows. The set of players is $\{F, B\}$, where F is the firm and B is the bank. Player F selects a strategy from the set $A^F = \{I, O\}$, where I is the choice of inside mode of coordination and O the choice of outside mode of coordination. Player B observes the choice of player F and selects a strategy from the set $A^B = \{RR, R\emptyset, \emptyset R, \emptyset\emptyset\}$, where RR represents the choice of granting the loan $[R]$ for any strategy of the firm, $R\emptyset$ and $\emptyset R$ the choice of granting the loan only when the firm selects I or O, respectively, and $\emptyset\emptyset$ the choice of granting no loan for any strategy of the firm.

The timing of the model is as follows.

1. At $t = 0$

- the firm sets a contingent production plan to exploit complementarity, chooses between internal and external modes of coordination and applies for K_a and $(K_a + C)$, respectively, to the bank;

- the bank decides whether to propose a take-it or leave-it loan or not; in the former case the parties sign the contract.

2. Between $t = 0$ and $t = 1$

- when the internal mode of coordinating is selected, the bank cannot verify whether the firm coordinates or not: a form of moral hazard is thus present;

- when the external mode is chosen, the firm credibly commits to coordinate: no moral hazard problem arises.

3. At $t = 1$ returns accrue, the firm, which has no time preference, starts production and repays the bank (in case of the outside mode it also pays the consulting company).

The analysis proceeds as follows. In the following two sections we study the characteristics of the loan proposed by the bank when the mode of coordination is chosen to be inside or outside, respectively, and the participation constraint of the bank is not binding.[6] In Section 5 we focus on two different cases, depending whether the bank's participation constraint is binding for some values of C (low complementarity case) or not (high complementarity case). We then analyse how the subgame perfect Nash equilibrium of the game changes with C in each of the two cases.

3 Inside Mode of Coordination

Consider the case in which the firm uses internal human resources to coordinate. The bank offers a loan $[R]$ to maximize its utility. Recall that $\Delta_c^2 < K_a$: when only R&D succeeds, the firm goes bankrupt even if $R = 1$.

If the firm coordinates, expected surplus amounts to $\Pi^C(1, 1)$ and it is shared between the firm, that obtains U^C, and the bank, that receives V^C. If the firm does not coordinate, surplus $\Pi(1, 1)$ is produced, the firm gets U and the bank gets V. In this case, one should note that with probability $p(1 - p)$ only marketing succeeds and firm's ability to repay depends on the bank's choice of R. If the bank decides to set $R > \frac{\Delta_a^2}{K_a}$, the firm goes bankrupt. On the contrary, when $R \leq \frac{\Delta_a^2}{K_a}$ the firm can repay the debt obligations. We show in the Appendix that at equilibrium

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[6]When the bank does not participate, i.e., when it does not grant the loan, the vector of utilities is $(\overline{U}, \overline{V})$.

the bank sets $R > \frac{\Delta_a^2}{K_a}$ for any value of C, hence $U = p^2 \left[(\Delta_a + \Delta_c)^2 - RK_a \right] - K_c$ and $V = p^2 RK_a + p(1-p) \Delta_a^2 + (1-p) p \Delta_c^2 - K_a$.

Program α is solved by the bank when it wants to induce the firm to coordinate:

$$\max_R V^C \qquad\qquad (\alpha)$$
$$s.t.\ U^C\ \geq\ U \quad (IC_\alpha),\ U^C \geq \overline{U} \quad (IR_\alpha),$$

where IC_α is the incentive compatibility constraint which states that firm's utility is higher when it coordinates and IR_α is the participation constraint which ensures that firm's utility in case of coordination is greater than the outside option.

Program β is solved by the bank when it induces the firm not to coordinate:

$$\max_R V \qquad\qquad (\beta)$$
$$s.t.\ U\ \geq\ U^C \quad (IC_\beta),\ U \geq \overline{U} \quad (IR_\beta),$$

where IC_β is the incentive compatibility constraint which states that firm's utility is higher when it does not coordinate and IR_β is the participation constraint which ensures that firm's utility when it does not coordinate is greater than the outside option.

The IC constraints are binding for:

$$R_{IC} = \frac{(\Delta_a + \Delta_c)^2}{K_a} - \frac{C}{(p - p^2) K_a}. \qquad\qquad (10)$$

The IR_α and IR_β constraints are binding when, respectively:

$$R_{IR_\alpha} = \frac{(\Delta_a + \Delta_c)^2}{K_a} - \frac{B_f K_c + C}{pK_a},$$

$$R_{IR_\beta} = \frac{(\Delta_a + \Delta_c)^2}{K_a} - \frac{B_f K_c}{p^2 K_a}. \qquad\qquad (11)$$

Henceforth we assume that the indifferent firm applies for the bank loan when the participation constraint is binding and decides to coordinate when the incentive constraint is binding. An ε reasoning may be used to make the argument more appealing.

Under symmetric information the bank would always leave the firm with the reservation utility and would prefer to induce coordination. Nevertheless, given that under inside mode C is non transferable, the choice of the firm is assumed to be nonverifiable and noncontractable. As a consequence, the bank faces a trade-off: its utility is linearly increasing in R, but when $R > R_{IC}$ (namely, the IC_β constraint is satisfied) the firm does not coordinate, thus reducing total surplus to be split. Under asymmetric information the bank is then forced to propose a lower interest rate to induce the firm to coordinate.

We analyze how the bank's choice of R changes with C. First of all, it is worth noting that

$$R_{IR_\alpha} < R_{IC} \iff 0 \leq C < C_1, \tag{12}$$

where $C_1 = \frac{1-p}{p} B_f K_c$. If C belongs to this interval (i.e., C is very small), informational asymmetry disappears because the bank knows that the firm, if participates, chooses coordination for any R. The interest rate is set such that the firm's utility is equal to the reservation value, namely R_{IR_α}. Surplus is shared in the following way:

$$V^C (R_{IR_\alpha}, C) = \Pi^C (1,1) - \overline{U} \tag{13}$$

to the bank, while the firm receives $U^C = \overline{U}$.

When $C_1 \leq C \leq \overline{C}$, we have $R_{IC} \leq R_{IR_\beta}$, where $\overline{C}$ derives from (3). The bank compares the utility when it sets R_{IC}, the maximum interest rate that induces coordination, with the one when it sets R_{IR_β}, the maximum interest rate that induces participation without coordination.

When the contract is $[R_{IC}]$, the bank gets

$$V^C (R_{IC}, C) = p (\Delta_a + \Delta_c)^2 - K_a - \left(1 + \frac{p}{1-p} \right) C, \tag{14}$$

while the firm obtains:

$$U^C (R_{IC}, C) = \frac{p}{1-p} C - K_c. \tag{15}$$

Note that $U^C (R_{IC})$ is increasing in C because it represents a compensation for the coordination cost. Moreover, $U^C (R_{IC}) \geq \overline{U} \Leftarrow C_1 \leq C \leq \overline{C}$: the firm receives an informational rent.

When the contract is $[R_{IR_\beta}]$, the bank's utility is

$$V (R_{IR_\beta}) = \Pi (1,1) - \overline{U} \tag{16}$$

and the firm receives the reservation utility.

Comparing the two possible utility levels of the bank, we obtain:

$$V^C (R_{IC}, C) \geq V (R_{IR_\beta}) \iff C \leq C_2, \tag{17}$$

where $C_2 = (1-p) [p (1-p) 2\Delta_a \Delta_c + B_f K_c]$. When $C > C_2$, the informational rent is so high that the bank finds it profitable not to induce coordination.

We make the following assumption:

Assumption 1 $p^2 2\Delta_a \Delta_c \geq B_f K_c \iff C_1 \leq C_2 \leq \overline{C}$.

The assumption states that the firm's outside option is low with respect to the complementarity gain. Henceforth we take into account the above interval. The expressions for the bank's utility and the firm's utility are the following:

$$\mathcal{V} = \begin{cases} V^C\left(R_{IR_\alpha}, C\right) = \Pi^C\left(1,1\right) - \overline{U} \iff 0 \leq C \leq C_1 \\ V^C\left(R_{IC}, C\right) = \Pi^C\left(1,1\right) - \left(\frac{p}{1-p}C - K_c\right) \iff C_1 < C \leq C_2 \\ V\left(R_{IR_\beta}\right) = \Pi\left(1,1\right) - \overline{U} \iff C_2 < C \leq \overline{C} \end{cases} \tag{18}$$

$$\mathcal{U} = \begin{cases} U^C\left(R_{IR_\alpha}\right) = \overline{U} \iff 0 \leq C \leq C_1 \\ U^C\left(R_{IC}, C\right) = \frac{p}{1-p}C - K_c \iff C_1 < C \leq C_2 \\ U\left(R_{IR_\beta}\right) = \overline{U} \iff C_2 < C \leq \overline{C} \end{cases} \tag{19}$$
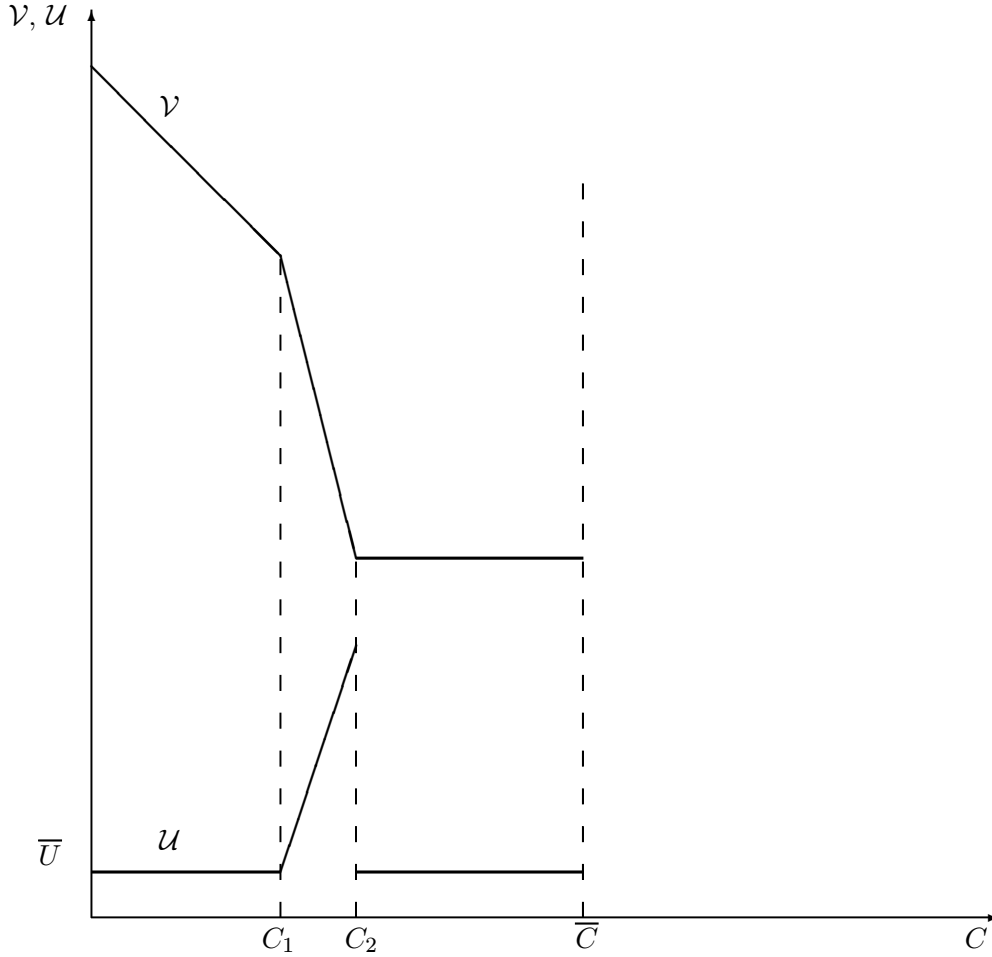

Figure 1 : Utility of the bank and utility of the firm under the inside mode of coordination.

Figure 1 represents the above utilities as a function of C. The utility function of the bank is piecewise linear and decreasing in C. In particular, it sharply decreases for $C \in (C_1, C_2]$ when the firm exploits the asymmetry of information to gain an informational rent. Note in fact that the utility function of the firm remains constant at its participation value except for $(C_1, C_2]$, where it is strictly increasing.[7]

4   Outside Mode of Coordination

Consider the situation in which the firm chooses to avail itself of outside coordination services, i.e., the firm pays C to a consulting company to obtain perfect correlation between the two activities. Coordination cost is now transferable and there is no moral hazard.

The bank proposes a loan $[R]$ where R is the (gross) interest rate. The amount of the loan increases to $(K_a + C)$ because the coordination action is now contractable: the bank observes the agreement between the firm and the consulting company and lends C to allow the firm to coordinate the activities. The choice of external mode is equivalent to a credible promise of coordination because we assume that the contract between the firm and the consulting company entails a sufficiently high rescission cost that the bank observes.[8]

The bank then solves the following problem:

$$\max_R V'^C \quad s.t. \ \ U'^C \geq \overline{U}, \tag{γ}$$

where U'^C and V'^C are defined by (8) and (9). The utility of the bank is at its highest when R is such that the constraint is binding. By solving $U'^C = \overline{U}$ for R, we have

$$R' = \frac{(\Delta_a + \Delta_c)^2}{K_a + C} - \frac{B_f K_c}{p\,(K_a + C)}. \tag{20}$$

The firm receives the reservation utility $\mathcal{U}' = \overline{U}$ and the bank gets:

$$\mathcal{V}' = V'^C\left(R', C\right) = \Pi^C\left(1, 1\right) - \overline{U}. \tag{21}$$

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[7] The lowest equilibrium interest rate for programs α and β is

$$\min\left\{R_{IR_\alpha}\left(C_1\right), R_{IC}(C_2), R_{IR_\beta}\right\} = \frac{\Delta_a^2 + \Delta_c^2}{K_a} + \frac{p^2 2\Delta_a \Delta_c - B_f K_c}{p K_a}$$

Assumption 1 ensures that this value is higher than $\frac{\Delta_a^2}{K_a}$.

[8] More precisely, if the firm decides to pocket C and not to coordinate, it has to pay an amount F to the consulting company to cancel the contract. In this case utility of the firm is given by $(C - F) + p^2\left[(\Delta_a + \Delta_c)^2 - R'(K_a + C)\right] - K_c$, where R' is defined by (21). This value is assumed to be lower than $\overline{U}$. By consequence the firm prefers to coordinate. Note also that for any $F > 0$ the utility of the firm when decides to pocket C and to coordinate by using internal resources is lower than $\overline{U}$.

In Figure 2 we depict the utility of the bank and the utility of the firm, when the latter chooses the outside mode.
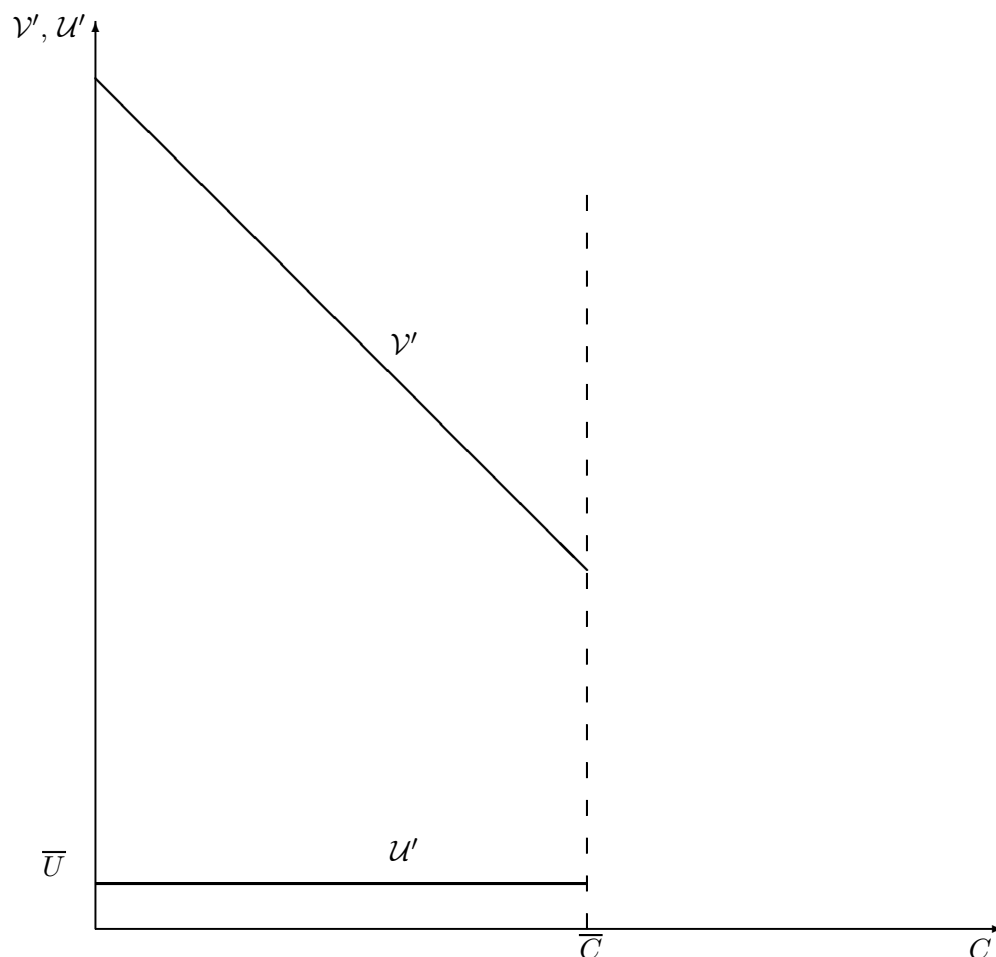

Figure 2 : Utility of the bank and utility of the firm under the outside mode of coordination.

5 Equilibrium Analysis

In this section we study the equilibrium of the model by taking into account the bank's decision of granting the loan and the firm's choice between the modes of coordination. One should remember the possibility for the bank to invest in alternative assets which give an utility equal to $\overline{V}$: the bank compares the utility that it extracts from financing the firm with returns from such alternative assets.

We consider two possible scenarios that depend on the relative level of complementarity.

Definition *(i) Complementarity is low if $V\left(R_{IR_\beta}\right) < \overline{V} \leq V^C\left(R_{IR_\alpha}, C_1\right)$; (ii) complementarity is high if $\overline{V} \leq V\left(R_{IR_\beta}\right)$.*[9]

The equilibrium analysis takes into account the utility of the firm and the utility of the bank as functions of C. The contracting game is solved by backward induction in order to study how the SPNE in pure strategies changes with C. We proceed in three steps:

1. We verify whether the bank offers the loan or not, by comparing the utility that the bank extracts from the complementary project to the outside option $\overline{V}$. If the former is lower the bank does not grant the loan and both the bank and the firm end up with their respective reservation utilities. If the opposite holds, the loan is granted.

2. We compare firm's utility under inside and outside modes of coordination and derive the choice between the two ones.

3. We compute the equilibrium level of surplus, i.e., the sum of the bank's and the firm's utility, as a function of C.

5.1 Low Complementarity and Equilibrium

We first consider the situation in which complementarity gains are low. We base the analysis on the examination of Figure 3, where we depict the utility of the bank and the utility of the firm under the two alternatives of inside and outside modes of coordination. The bold lines represent the equilibrium utilities.

Let $C_\emptyset$ and $C'_\emptyset$ be defined by the intersection between the straight line $\overline{V}$ and, respectively, $V^C\left(R_{IC}, C\right)$ and $V'^C\left(R', C\right)$:

$$
\begin{aligned}
C_\emptyset &= (1-p)\left[p\left(\Delta_a + \Delta_c\right)^2 - K_a - \overline{V}\right], \\
C'_\emptyset &= p\left(\Delta_a + \Delta_c\right)^2 - K_a - B_f K_c - \overline{V},
\end{aligned}
$$

with $C_1 \leq C_\emptyset \leq C'_\emptyset \leq \overline{C}$ by construction.

First note that for $C \in [0, C_\emptyset]$ the utility of the bank if the loan is offered is not lower than $\overline{V}$, therefore its equilibrium strategy is $(\mathcal{RR})$ in such an interval.

For very low values of C (i.e., $C \in [0, C_1]$) information is symmetric under both modes hence the firm receives $\overline{U}$ and is indifferent between inside and outside coordination. There are two SPNE: $(I, \mathcal{RR})$ and $(O, \mathcal{RR})$. For $C \in (C_1, C_\emptyset]$ if the firm chooses the inside mode a moral hazard

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[9]We omit two other (meaningless) cases that appear for very low values of complementarity, i.e. $V^C\left(R_{IR_\alpha}, C_1\right) < \overline{V} \leq V^C\left(R_{IR_\alpha}, 0\right)$ and $V^C\left(R_{IR_\alpha}, 0\right) < \overline{V}$.

problem arises. In this case the bank offers $[R_{IC}]$, the firm then coordinates and receives an informational rent which makes its utility strictly higher than the utility under the outside mode: $U^C(R_{IC}, C) > \overline{U}$. The SPNE is $(I, \mathcal{RR})$.
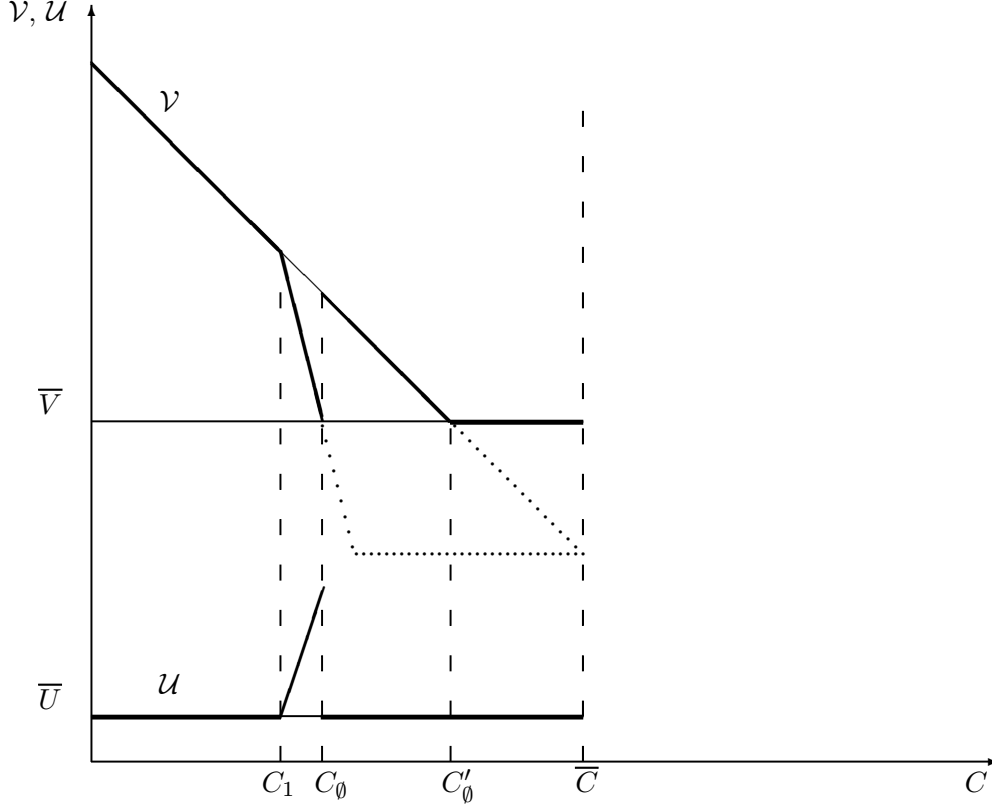

Figure 3 : Low complementarity and equilibrium.

The most interesting case arises for $C \in (C_\emptyset, C'_\emptyset]$, where the bank does not grant the loan if the firm chooses the inside mode because the informational rent is too high, while it keeps on contracting under the outside mode, where no informational rent is paid. The firm always gets the reservation utility, but, given that it prefers to participate, it chooses the outside mode and the bank proposes $[R']$. The SPNE is $(O, \emptyset\mathcal{R})$.

For $C \in (C'_\emptyset, \overline{C}]$ the bank does not grant the loan for any strategy of the firm because its outside option is more profitable, therefore the firm invests in bonds. Two are the SPNE: $(I, \emptyset\emptyset)$ and $(O, \emptyset\emptyset)$.

When complementarity is low maximum surplus is given by $\Pi^C(1,1)$ for $C \in [0, C'_\emptyset]$.[10] It is easy to verify that equilibrium surplus is always at its highest. We focus on the interval $C \in (C_\emptyset, C'_\emptyset]$ to state the following:

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[10] For $C \in (C'_\emptyset, \overline{C}]$ the maximum surplus is $(\overline{V} + \overline{U})$.

Proposition 2 *When complementarity is low, the firm prefers the outside mode of coordination, otherwise it does not receive the loan. Surplus is at its highest.*

When complementarity is low and the firm bears a relatively low cost of coordination, then it uses internal human resources because the nontransferability of C gives an additional informational rent. On the other hand, when the cost is relatively high, the firm avails itself of the outside consulting because the transfer of C eliminates the moral hazard problem and makes the loan feasible. It is worth noting that surplus is maximum because the firm always decides to coordinate.

5.2 High Complementarity and Equilibrium

Consider the case in which complementarity gains are high. We base the analysis on the examination of Figure 4, which represents an upward shift of the utility function of the bank (and/or a downward shift of $\overline{V}$) with respect to Figure 3. As before, the bold lines denote the utility of the bank and the one of the firm in equilibrium. Notice that the utility of the bank of it offers the loan is higher than $\overline{V}$ for any C, then its equilibrium strategy is $(\mathcal{RR})$: the loan is always granted.

For $C \in (0, C_1]$ information is symmetric under both types of coordination and the firm gets the reservation utility anyway: again, the SPNE are $(I, \mathcal{RR})$ and $(O, \mathcal{RR})$. For $C \in (C_1, C_2]$ a moral hazard problem arises under the inside mode. In this case, given that the bank offers $[R_{IC}]$, the firm coordinates and receives an informational rent which makes its utility higher than in case of the outside mode: $U^C (R_{IC}, C) > U'^C \Longleftarrow C_1 < C \le C_2$. The SPNE is $(I, \mathcal{RR})$.

The most interesting case arises for $C \in (C_2, \overline{C}]$, where the firm gets the reservation utility under both modes. If it chooses the inside mode, then the bank proposes $\left[R_{IR_\beta} \right]$ and the firm does not coordinate, while if it chooses the outside one, the bank offers $[R']$ and the firm coordinates. There are two SPNE: $(I, \mathcal{RR})$ and $(O, \mathcal{RR})$.

In case of high complementarity the firm does not strictly prefer outside coordination for any value of C. Maximum surplus is given by $\Pi^C (1, 1)$, but in $(C_2, \overline{C}]$ equilibrium surplus is $\Pi (1, 1) < \Pi^C (1, 1)$ when the firm chooses the inside mode.

We focus on the interval $C \in (C_2, \overline{C}]$ to state the following:

Proposition 3 *When complementarity is high, the firm is indifferent between the two modes of coordination. If the inside mode is chosen surplus is not at its highest.*

It is worth noting that the firm can decide not to resort to the outside mode because there is no threat of credit rationing. This leads to a smaller surplus because the bank prefers to induce the firm not to coordinate. The shaded area in Figure 4 represents such a potential loss of surplus.
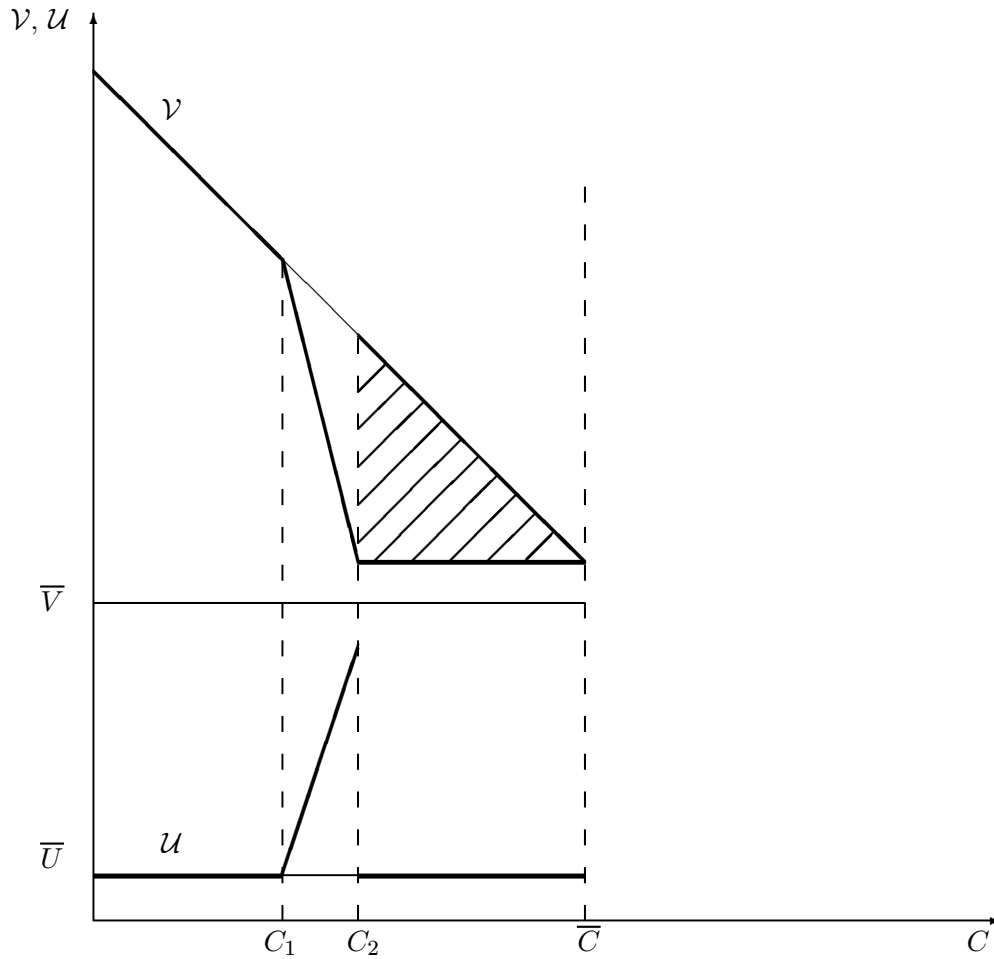
Figure 4 : High complementarity and equilibrium.

6 Conclusion

In this paper we analyze the investment problem of an entrepreneurial start-up firm which applies for a bank loan to implement a production project based on two complementary activities, demand enlargement and cost reduction. At the very heart of our model lies the assumption that firms can improve the complementarity effect by coordinating the activities, thus streamlining the production process. Coordination consists of ameliorating the flow of information between the units that are in charge of the two investment activities. Surplus of the project is at its highest when activities are coordinated. We consider two modes of coordination: inside, where the firm reallocates internal human resources, and outside, where it resorts to a consulting company's competency. The choice of coordination is not verifiable by the bank in the former case and a moral hazard problem arises,

while in the latter one information is symmetric.

We consider the equilibrium repayment as a function of the coordination cost. Two scenarios are taken into account: low complementarity, when the utility that the bank extracts from the complementarity project is lower than the average return of alternative assets if the inside mode is implemented, and high complementarity, when such an utility is higher. In case of low complementarity, the firm is obliged to resort to the outside company, otherwise it does not receive the loan. Equilibrium surplus is at its highest. In other words, the firm that offers a not very profitable project faces the risk of not getting funded. When this is the case, it prefers to give up the informational rent and hire the consulting company. The equilibrium outcome is efficient because the firm credibly commits to coordinate. On the contrary, when the complementarity gain is high, the firm never strictly prefers the outside mode of coordination because of absence of a credit rationing threat. However, surplus is maximum only if the firm delegates the coordination task to an outside agent. In fact the informational rent paid by the bank under the inside mode becomes excessive and the bank prefers then to induce no coordination.

The role of consulting companies is justified in the current model as a means of mitigating informational problems in credit markets where projects are characterized by complementarity and coordination. More exactly: (i) worthwhile productive projects, that without the consulting option would not have been funded, are undertaken; (ii) the firm efficiently performs the productive project, i.e., it coordinates the activities that without the consulting option would not have been.

7 Appendix

Bankruptcy or not bankruptcy?   Consider the case in which the bank decides to set $R \leq \frac{\Delta_a^2}{K_a}$, then the firm does not go bankrupt when only marketing succeeds. We limit our attention to the new IC constraint,

$$U^C \gtreqless U'' \tag{A1}$$

where $U'' = p^2 \left[(\Delta_a + \Delta_c)^2 - RK_a \right] + p(1-p) \left[\Delta_a^2 - RK_a \right] - K_c$ represents the utility of the firm when it does not coordinate. The left hand side of the IC constraint is greater than the right hand side if and only if

$$C < p(1-p)\left(2\Delta_a \Delta_c + \Delta_c^2 \right) \tag{A2}$$

which is always true because $\overline{C} < p(1-p)\left(2\Delta_a\Delta_c + \Delta_c^2\right)$. The firm, if it participates, always chooses coordination when $R \leq \frac{\Delta_a^2}{K_a}$ and the bank solves the following program:

$$\max_R V^C$$
$$s.t. \quad U^C \geq \overline{U}$$

Given that V^C is linearly increasing in R, the bank sets $R^* = \frac{\Delta_a^2}{K_a}$ and obtains $V^C(R^*) = p\Delta_a^2 - K_a$. The firm gets $U^C(R^*) = p\left(\Delta_c^2 + 2\Delta_a\Delta_c\right) - C$, which is strictly greater than $\overline{U}$ for Assumption 1, hence the firm participates.

On the other hand, the minimum utility of the bank in the bankruptcy case is $V\left(R_{IR_\beta}\right) = \Pi(1,1) - \overline{U}$, which can be rewritten as

$$V\left(R_{IR_\beta}\right) = p\left(\Delta_a^2 + \Delta_c^2\right) - K_a + p^2 2\Delta_a\Delta_c - B_f K_c. \tag{A3}$$

It is easy to verify that:

$$V^C(R^*) < V\left(R_{IR_\beta}\right) \iff B_f K_c < p\Delta_c^2 + p^2 2\Delta_a\Delta_c \tag{A4}$$

which holds for Assumption 1. We then rule out the possibility for the bank to set $R \leq \frac{\Delta_a^2}{K_a}$ at equilibrium.

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